Identifying Sensitive Structural and Hydraulic Parameters in a Bridge-Stream Network for Flood Mitigation Planning

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Abstract

Perturbations to hydraulic structures can have significant and far-reaching consequences, including both hazard attenuation and intensification. Quantitative analysis of the dynamic interactions between a river and its surrounding infrastructure under high-risk, transient conditions may help prioritize limited resources available for bridge and river rehabilitations, holistic design of bridges, and address stakeholder concerns raised in response to planned bridge and infrastructure alterations.

Study Area

- Otter Creek between Rutland and Middlebury, VT
- Low gradient 0.02-<0.1%
- 12 road and 8 rail bridges
- 75 miles of town- and state-owned road and 30 miles of state-owned rail lie within the floodplain
- Several overflow bridges and more than one hundred culverts
- Mad River between Warren Village and Moretown, VT
- Mid to High gradient 0.1-<5%
- 15 road bridges and two breached dams
- Over 62 miles of town- and state-owned road

Computer Model

- Built 2D unsteady HEC-RAS model of 40 mi^2 of the Otter Valley
- Calibrated to gauged Tropical Storm Irene (Q500) flows and surveyed high water marks
- Verified fidelity for several additional flood events
- Currently building a 2D unsteady HEC-RAS model of the Mad River

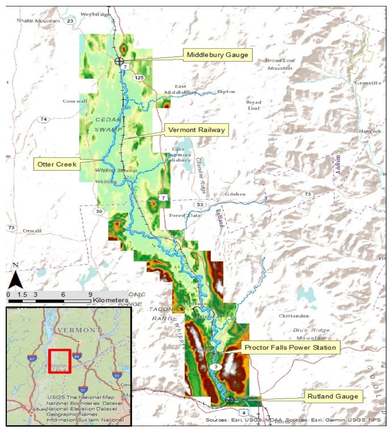


Figure 1. Otter Creek study area. The USGS operates flow gauges in Rutland and Middlebury, 46 river miles apart.

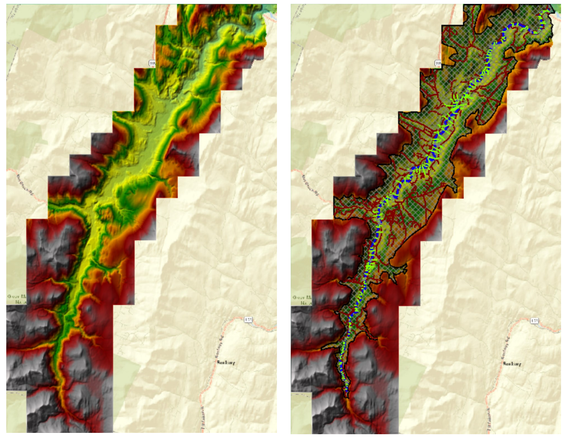
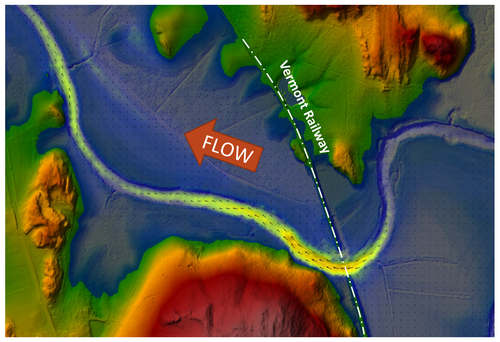


Figure 2. Beginning stages of the 2D HEC-RAS model for the Mad River study area.

Otter Creek Analysis

Sensitive structural and hydrogeological features are determined by simulating perturbations, including raising roadway grades, increasing bridge span lengths, and removal of encroaching structures. Local changes can impact the response of the entire watershed.



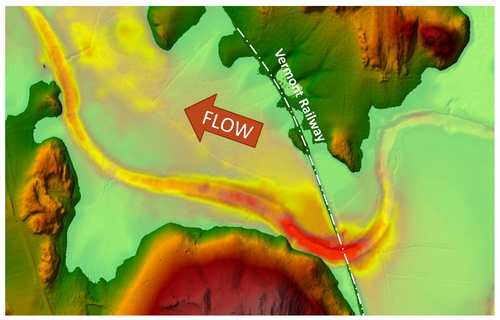


Figure 3. Velocity is increased by 225% from constriction at VT Railway Bridge 220 in Pittsford (compared to no bridge). Higher velocities propagate to the next crossing, 0.9 miles downstream, and cause a >4% increase in peak stream power at the Syndicate Rd bridge.

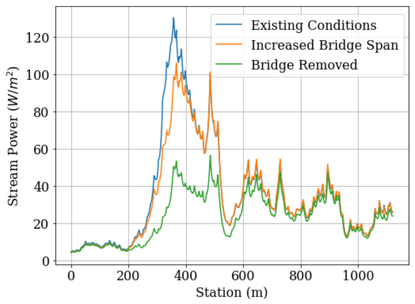
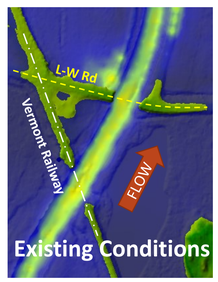
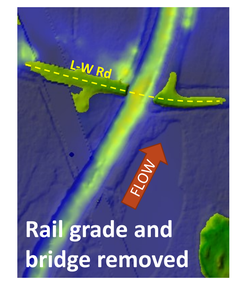


Figure 4. Stream power through VTRR bridge 220 (left). Doubling the length of the span reduces peak by 20% (right).





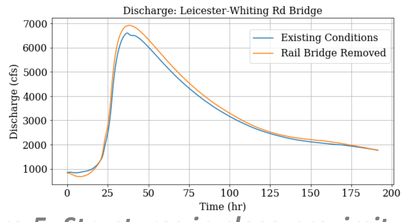


Figure 5. Structures in close proximity have significant interaction. Here, simulated removal of a railroad grade and bridge 400' upstream of a road bridge results in a 16% increase in peak discharge, and 11% increase in stream power through the 2nd bridge.

Conclusions and Ongoing Research

- The Otter Creek analysis indicates alterations could have both positive and negative consequences within the corridor. The Tropical Storm Irene model showed attenuation of peak discharge by 5 hrs and 500 cfs (8%) in Middlebury, but an average increase in inundation duration of 20 hrs and additional flood depths of 0.25 ft throughout the basin.
- Individual perturbations to bridges intended to improve local hydraulics may result in a reduction of backwater flooding, while also allowing faster flood wave propagation through the adjusted structure. This especially may have undesirable consequences if downstream structures rely on the retardation effects of upstream structures for resiliency.
- A future analysis will be done on the medium-to-high gradient Mad River and another location.
- The results from the three study sites will be compared to better understand the interactions between rivers and surrounding infrastructure in varying river gradients.

Acknowledgments

Funding supports provided by the Vermont Agency of Transportation and the Transportation Infrastructure Durability Center at the University of Maine by a grant from the U.S. DOT's UTC program are greatly appreciated. The authors thank Eliza Jobin-Davis and Eric Romero for their help in field data collection. The authors are grateful to Cassidy Cote, Jaron Borg, Nick Wark and Drs. Emily Parkany and Ian Anderson for their valuable feedback.